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A new vascular plant Red List for Great Britain

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Abstract: This report presents a comprehensive revision of the Great Britain (GB) Red List for all native and archaeophyte vascular plants, utilising verified datasets published by the Botanical Society of Britain and Ireland (BSBI) covering three distribution atlas time periods (1930-1969; 1987-1999; 2000-2019). Assessments of threat were undertaken using the latest International Union for Conservation of Nature (IUCN) Guidelines and Criteria. Of 1720 taxa evaluated, 434 (25%) were assessed as Critically Endangered (55), Endangered (117) or Vulnerable (262). A further 22 taxa were assessed as Regionally Extinct, and 140 as Near Threatened. Factors associated with threat included rarity, the intensification of management, long-term neglect, development, eutrophication and pollution. Such factors have had a disproportionate impact on the flora of lowland regions. An elevated threat status for numerous historically widespread 'positive indicator' taxa of semi-improved terrestrial habitats, and those of wetland and aquatic habitats, was associated with the degradation or destruction, and increased fragmentation, of suitable habitat, with such taxa increasingly confined to protected refugia. For a small number of montane plants present at their absolute southern European range limits in GB, threat was also linked to the symptoms of climate change.

Contents

1 Introduction

A Red List assessment measures extinction risk under the prevailing circumstances using independent and standardised International Union for Conservation of Nature (IUCN) criteria relating to aspects of population change and range expansion or contraction (Mace *et al.*, 2008). A taxon is assigned to a threat category if it meets the quantitative threshold for at least one criterion. Red List data are regularly used in applied and theoretical conservation research, and contribute to conservation planning and priority setting. For example, threatened taxa are now included in the revised guidelines for the selection of biological Sites of Special Scientific Interest in Great Britain (Taylor *et al.*, 2021).

Extremely rare taxa based on small population size and/or restricted geographic range are captured in an assessment of threat, but rarity *per se* is not directly reflected in a Red List classification, in part because some naturally rare, highly range-restricted taxa have life-history strategies to enable substantial long-term persistence (Gaston, 1994). It follows that an assessment of threat should sometimes be used in conjunction with other competing factors (Collen *et al.*, 2016). For example, an endemic taxon might not meet the necessary criteria for a classification of 'threatened', but could be both uncommon and of global importance. Similarly, a taxon that is not listed as threatened but is known to be an indicator of high-quality semi-natural vegetation might also be viewed as having high conservation priority.

The first GB Red List to use IUCN criteria to assess all native and archaeophyte taxa was published as part of the JNCC Species Status Assessment project (Cheffings & Farrell, 2005). This List compared records collected for the *New Atlas of the British and Irish Flora* (Preston *et al.,* 2002) with those for the *Atlas of the British Flora* (Perring & Walters, 1962). Subsequent to this, regular revisions were undertaken (Leach, 2007, 2010, 2017, 2019; Leach & Walker, 2011, 2013, 2015), the majority reflecting the availability of more recent data collected for rare taxa, additions due to the discovery of new taxa, or changes due to the reassignment of taxa according to native/archaeophyte/neophyte status. The publication of the *Vascular Plant Red List for England* (Stroh *et al.*, 2014) also led to numerous revisions in the GB List for taxa that were present in England only. Following the publication of *Plant Atlas 2020* (Stroh *et al.*, 2023), it became possible to use the verified atlas dataset, which included an additional *c.*30 million records collected since Preston *et al.* (2002), to analyse more recent trends and produce a thorough revision of the GB Red List according to the most recent IUCN Red List assessment criteria (IUCN 2016, 2024).

The preparation of this Red List, which updates threat assessments for all native and archaeophyte vascular plant taxa present in GB, assists in the Government's aim, published in the UK's National Biodiversity Strategy (Department of Agriculture, Environment and Rural Affairs *et al.,* 2025), of halting and reversing biodiversity loss globally by 2030. Specifically, it addresses target 21, which aims to "ensure that knowledge is available and accessible to guide biodiversity action". It is also one of the UK's *Global Strategy for Plant Conservation* targets (see Sharrock, 2012).

This publication has been produced by a working group (the Species Status Assessment Group) with representation from a range of independent experts and interested organisations, including the Botanical Society of Britain and Ireland, Natural England, Natural Resources Wales, NatureScot, the Biological Records Centre (within the UK Centre for Ecology & Hydrology), the Natural History Museum, Plantlife International, Royal Botanic Garden Edinburgh, and the Royal Botanic Gardens Kew.

2 Coverage

2.1 *Taxonomic coverage*

The scope of this project was all vascular plants, comprising pteridophytes (ferns and fern allies) and spermatophytes (gymnosperms and angiosperms). Therefore, the two starting points for the project were *Plant Atlas 2020* (Stroh *et al.*, 2023) and the *New Flora of the British Isles* (Stace, 2019). Status categorisations in *Plant Atlas 2020* were based on the available evidence and discussions within the Species Status Assessment Group. Taxa were included if they were classified in Stroh *et al*. (2023) as native, native-or-alien, or archaeophyte in Great Britain (see section 2.3; see also Stroh *et al*. 2024). Apomictic groups and critical taxa omitted from *Plant Atlas 2020* were also included wherever possible (see section 2.4). Neophyte taxa were excluded, as were taxa treated by Stace (2019) at ranks below that of subspecies, although records at varietal level are by default included within the distributional analysis of the associated species or subspecies.

2.2 *Geographical coverage*

The scope of this work is confined to Great Britain *i.e.* England, Wales and Scotland, and therefore excludes both the Channel Islands and the Isle of Man. Red List assessments of vascular plants for the island of Ireland (covering both Northern Ireland and the Republic of Ireland) can be found in Wyse Jackson *et al.* (2016).

2.3 *Status*

A native plant is either one which arrived in the study area without intervention by humans, having come from an area in which it is native, or one which has arisen *de novo* in the study area. Some taxa have been classified, using a precautionary approach, as 'native-or-alien', with a lack of conclusive evidence one way or the other meaning their native/alien status could not be 'proved beyond all reasonable doubt'; these are treated in this Red List in the same way as unequivocal native taxa. Archaeophytes are defined as plants which were brought to our area by humans, intentionally or unintentionally, and became naturalised between the start of the Neolithic period (*c.*4000BC in GB) and AD1500. A neophyte is a plant that was first introduced after AD1500, intentionally or unintentionally, or if present before AD1500, that occurred only as a casual and is naturalised now only because it was reintroduced subsequently. The year AD1500 was chosen as it marks the beginnings of radical change in patterns of human demography, agriculture, trade and industry; also, it is close to the European discovery of North America in 1492. A detailed discussion of the concept of archaeophytes and the criteria used to categorise them can be found in Preston *et al.* (2004).

2.4 *Apomictic and critical groups*

Apomictic taxa reproduce by seed produced without fertilisation or, in ferns, by apogamy, *i.e.* the formation of a sporophyte directly from gametophyte tissue. They are thus genetically identical to their parent, aside from other sources of mutation such as somatic and transposable-element–mediated changes. Critical taxa are broadly defined here as plants that may hybridise extensively, or have multiple inbred lines, which makes them unusually difficult to identify at the species level. Cheffings & Farrell (2005) did not include the large apomictic genera (*Hieracium, Rubus, Taraxacum*) in full, although exceptions were made when there was thought to be sufficient distributional data for a credible assessment (*e.g.* the inclusion of *Hieracium* Section *Alpina*; the few *Rubus* taxa that are endemic and restricted to five or fewer hectads; a few native *Taraxacum* species). For other apomictic or critical groups, species or segregates were included in the Main List, Waiting List or Parking List as appropriate (see Cheffings & Farrell, 2005, pp. 6-9).

Since the publication of the 2005 *Red List*, there has been considerable focus in some quarters on the recording of critical groups, with recorders assisted by a range of recent publications, including BSBI Handbooks, Floras and field guides (*e.g.* Lynes, 2022; Merryweather, 2020; Metherell & Rumsey, 2018; Rich & Scott, 2011; Rich *et al.,* 2014; Rich & McCosh, 2021; Richards, 2021; Sell & Murrell, 1996-2018; Shaw, 2020). This has resulted in a much better understanding of the distribution of such taxa in GB than was available for the 2005 *Red List*, to the extent that it has been possible to include here, in full, threat assessments for *Hieracium* and *Taraxacum* (see Appendices 3 and 5 respectively). In addition, threat assessments for segregates within the *Dryopteris affinis* and *Limonium binervosum* aggregates are included in Appendices 2 and 4 respectively. Assessments for taxa included within Appendices 2-5 were based on a combination of expert opinion, the known mapped distributions and the published literature. Unfortunately, an initial evaluation of the available distributional data found that there was insufficient information to assess *Rubus* in full; the vast majority of taxa within this genus have therefore been placed on the Waiting List (see section 9), pending further study and with the hope that they can be assessed in a future revision of the GB Red List.

Of the remaining apomictic or critical groups mentioned in Cheffings & Farrell (2005), all native *Euphrasia*, *Salicornia* and *Sorbus* taxa are included in Appendix 1 (Main List), save for three *Sorbus* taxa (*S. humphreyana, S. subeminens, S. waltersii*) described in Sell & Murrell (2014) which require further study in terms of their taxonomic validity and, if accepted, their distributions; in the meantime, these taxa have been placed on the Waiting List. Apomicts within the *Ranunculus auricomus* complex described by Leslie (1978) and included in Sell & Murrell (2018) have also been placed on the Waiting List, pending further information concerning both their distribution and the description of additional taxa within this complex.

The genus *Dactylorhiza* has been the subject of numerous morphological and molecular studies since the publication of the 2005 *Red List* (*e.g.* Bateman, 2011; Hedrén *et al.,* 2011; Bateman & Denholm, 2012; Brandrud *et al.,* 2020; Bateman *et al.,* 2023), which – along with the recent comprehensive review of British orchids by Bateman (2022) – has in turn influenced here the inclusion of taxa in either the Red

List, Waiting List or Parking List. Likewise, critical reviews of *Epipactis* (*e.g.* Hollingsworth *et al.,* 2006; Brys & Jacquemyn, 2016; Sramkó *et al.,* 2019; Bateman, 2020) have led to a fuller understanding of the taxa present in GB, resulting in one taxon previously assessed as Endangered in 2005, *E. sancta*, being placed on the Waiting List, the inclusion of an additional taxon, *E. helleborine* subsp. *neerlandica* (albeit currently as Data Deficient) on the Main List, and threat assessments assigned to two taxa, *E. dunensis* and *E. leptochila s.s.*, that were previously on the Main List but categorised as Data Deficient.

In addition to the critical genera mentioned above, we have included in the Waiting List all *Ulmus* species published in Sell & Murrell (2018) which were largely based on earlier work by Armstrong (1992). *Ulmus* taxa are notoriously problematic to identify, with variation within the genus either viewed as comprising perhaps three, four or five species or, alternatively, many tens of species; Armstrong & Sell (1996) summarised well the confusion of the field botanist when they commented that "elms are usually overlooked or regarded with despair." Our knowledge of the distribution of *Ulmus* species included in Sell & Murrell (2018) is likely to be greatly assisted if the 2018 key and a complementary key published by Eversham (2021) are used widely, but these came too late to assist assessments of threat in the present Red List.

2.5 *Hybrids*

The 2005 *Red List* included threat assessments for 42 hybrid taxa, based in part on the rationale set out in Preston (2004). Hybridisation followed by polyploidy is one of the main mechanisms in plant speciation, and hybrids therefore have an important role to play in plant evolutionary processes. However, the IUCN Guidelines (2024) do not permit the inclusion of hybrids in a Red List assessment unless the hybrids, including apomictic plant hybrids, are recognised as species in their own right, *e.g. Senecio eboracensis, Spartina anglica*. This recognition has typically depended upon the degree of fertility and hence ability to self-perpetuate, although in some apomictic groups, such as *Sorbus,* specific status has not been applied until multiple individuals are known. This meant that hybrid taxa which are not (or not yet) considered separate species could not be formally assessed in this Red List, despite many hybrid taxa being of conservation concern.

3 Data sources

Validated records at the hectad (10 km × 10 km) scale provided from the BSBI's Distribution Database (DDb) were used to evaluate trends through time in relation to IUCN Criterion A (see section 4.2). There have been three atlas surveys covering GB, all mapped at the hectad scale. The majority of records for the first *Atlas* (Perring & Walters, 1962) were collected in the 1950s, although 1930 was chosen as the dividing line between contemporary and historic records for distribution maps, and the momentum built up by the atlas project continued after publication, such that data used for our analysis (and previous Red List analyses) in relation to the first *Atlas* spans the time period 1930-1969. Its successor (Preston *et al.,* 2002) mapped the distributions of vascular plant records collected between 1987 and 1999, whilst the third *Atlas* (Stroh *et al.,* 2023) collected field records from 2000 to 2019.

Although a substantial number of records were collected for the period 1970-1986, thus bridging the gap between the first and second atlas projects, data collected during this time period were not used in the modelled analysis. This is because the recording effort, relative to the three atlas recording projects, was too much at variance with species' true relative frequencies for the recording effort adjustment model used to be valid (Hill, 2012). Further guidance on the use of GB occurrence data for analyses can be found in Pescott *et al.* (2018).

Detailed published and unpublished reports concerning population studies of particular taxa were also used to inform assessments, particularly so for nationally rare taxa *i.e.* those present in ≤15 hectads, but also for taxa present in 16-30 hectads. This is partly because of the higher uncertainty in the modelled results associated with such taxa, but also due to the fact that such rare species are likely to be totally censused at the hectad scale regardless of time period, thereby potentially undermining (*i.e.* biasing) the model used to adjust for changing recording effort. Botanists who were known to have contemporary knowledge of such species were contacted directly and asked for their help; for example, Plantlife provided information on many Breckland rarities via Jo Jones and the Breckland Flora Group. Similarly, numerous BSBI Vice-County Recorders, Referees and other experts provided detailed accounts of rare taxa in their respective areas, including population counts and observed trends over time. Unpublished Site Condition Monitoring surveys funded by NatureScot (formerly Scottish Natural Heritage) were also of great assistance when assessing rare montane taxa, as were reports produced for Natural England and Natural Resources Wales. Such data were frequently used to assess threat on Criteria B-D.

4 Application of IUCN criteria

4.1 *IUCN threat categories and criteria*

The IUCN criteria represent the accepted method of assessing threat when producing Red Lists, both nationally and internationally. We have, therefore, adopted the standard categories and criteria published by IUCN (2012) and have made extensive use of the *Guidelines for Using the IUCN Red List Categories and Criteria* published in 2024. The four criteria (A-D) used for each assessment of threat are described in detail in Table 1. A fifth criterion, E, which assesses the probability of extinction in the wild on the basis of quantitative analysis, such as population viability studies, has not been used in this Red List as so few such analyses have been published. This approach is consistent with that followed by Cheffings & Farrell (2005) and other relevant vascular plant Red Lists such as Wyse Jackson *et al.* (2016) and Rivers *et al*. (2019).

4.2 *Application of Criterion A*

4.2.1 *Time periods for trend statistics*

The lifespans of plants have the largest variation and the absolute record in longevity of all organisms: from just a few weeks to thousands of years. Perhaps

Table 1. Modified from IUCN (2024), the table summarises the four criteria (A–D) and the relevant subcriteria that were used when assessing the IUCN threat status of a taxon. See section 4.6 for more information concerning the quantitative thresholds for Near Threatened (NT). If a taxon did not meet the relevant thresholds, it was assessed as Least Concern (LC), or if there was insufficient distributional information to arrive at an assessment of threat, Data Deficient (DD) (see section 7.1.4)

	Critically Endangered (CR)	Endangered (EN)	Vulnerable (VU)	Near Threatened (NT)
A. Population reduction	≥80%	≥50%	≥30%	≥28%
Sub-criterion A2: Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased or may not be understood or may not be reversible, based on sub-criteria (a) direct observation and/or (c) a decline in Area of Occupancy (AOO), Extent of Occurrence (EOO) and/or habitat quality.				
B. Geographic range				
Sub-criterion B1: EOO	<100 km^2	<5,000 km^2	<20,000 km^2	
Sub-criterion B2: AOO	<10 km^2	<500 km^2	<2,000 km^2	
AND at least 2 of the following *[1 of the following for Near Threatened]*:				
(a) Number of locations	1	≤5	≤10	
(b) Continuing decline in any of: (i) EOO; (ii) AOO; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals.				
(c) Extreme fluctuations in any of (i) EOO; (ii) AOO; (iii) number of locations; (iv) number of mature individuals				
C. Small population size and decline				
Number of mature individuals	<250	<2,500	<10,000	
AND				
Sub-criterion C2: A continuing decline				
AND				
C2 (ai) Number of mature individuals in each subpopulation:	<50	<250	<1,000	
OR				
C2 (aii) % individuals in one subpopulation =	90-100%	95-100%	100%	
D. Very small or restricted population				
Either: Number of mature individuals	<50	<250	D1. <1,000 **AND/OR**	<1,500
VU D2. Restricted number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time			D2. number of locations ≤5	

inevitably, there are considerably more data available in the literature for the lifespan of short-lived taxa than for long-lived perennial taxa. Even then, as Dietz & Schweingruber (2002) noted, "Despite its importance, data on the age of a plant … [is] still one of the least accessible parameters in the life history of plants, especially in herbaceous plants."

The IUCN Guidelines (2024) state that for Criterion A, an assessment of population trend should be measured over the past 10 years or three generations, whichever is longer. For the previous GB Red List, Cheffings & Farrell (2005) stated that the detailed information required for a measure of generation length was lacking for almost the entirety of the British flora. Consequently, they decided not to extrapolate or interpolate the trend data to an estimate of generational length. Rather, trends used for an assessment of threat under Criterion A were based on the two verified atlas datasets that were available at the time (Perring & Walters, 1962; Preston *et al.,* 2002), regardless of generation length. This approach was also followed for the Red Lists for Wales (Dines 2008), England (Stroh *et al.,* 2014) and Ireland (Wyse Jackson *et al.,* 2016). Since the publication of these Lists, a third atlas (Stroh *et al.,* 2023) has been published, with data collected and verified for the period 2000-19.

Given the ongoing paucity of information on generation length, and also the difficulties in interpolating this information based on the verified distribution data available, we have used a comparison of the first atlas time period (1930-1969) with the third atlas time period (2000-2019) *i.e.* the long-term trend, and a comparison of the second atlas (1987-1999) and third atlas time periods *i.e.* the short-term trend, as a proxy for generation length when assessing trends for Criterion A. If a taxon has an estimated lifespan of more than *c.*15 years, then the long-term trend is used to assess threat, as three generations (*c.*45 years), counting back from the end of field recording in 2019, would predate the start of field recording for the 1987-99 time period. If a lifespan was determined to be less than *c.*15 years, then threat was assessed for Criterion A using the short-term trend.

4.2.2 *Assigning taxa to a short- or long-term trend for analysis*

In order to segregate taxa into either the long-term or short-term trend, it was first necessary to undertake a comprehensive literature review of the lifespans of the taxa being assessed. During this process, we drew heavily on the Biological Flora of the British Isles series, published in the *Journal of Ecology*, and corresponding species accounts published in the Biological Flora of Central Europe (see Poschlod *et al.,* 1996). Schweingruber & Poschlod (2005), who describe the lifespan for hundreds of species present in Central Europe by analysing growth rings, was also a significant source of information. Their technique for aging, known as herbochronology, is adapted from dendrochronology and uses the growth rings in the secondary xylem of the root collars in order to determine longevity. Landolt *et al.* (2010) also present lifespan information for hundreds of herbaceous species using annual ring count data on aerial stems, root collars and rhizomes. Results concerning lifespans that were included in the analyses presented in Schweingruber & Poschlod (2005) were kindly made available by Peter Poschlod, and Michael Nobis sent us digital tables included in Landolt *et al.* (2010) for ease of interrogation. Other significant sources of information that were useful for helping to determine the lifespan of a taxon (*e.g.* traits such as perennation, lifeform, clonality) are presented in PLANTATT (Hill *et al.,* 2004), the LEDA Traitbase (Kleyer *et al.* 2008), CLO-PLA3 (Klimeš & Klimešová 2019) and Bender *et al.* (2000). Information on lifespan included in numerous other papers published in the peer-reviewed and grey literature were also used for taxa not covered by the sources noted above.

In instances where there were multiple published lifespans for a species which differed from each other, then the longest lifespan was applied. A strong element of expert opinion was inevitably involved in decision-making, especially for those taxa that did not have any published information. For example, there is very little evidence for the lifespan of British ferns, and the limited information that is available reflects the fact that for some, their lifespan could be equated to the longevity of seed-bearing trees (Dyer, 2013). We have, therefore, treated the majority of ferns as long-lived, although there are exceptions to this rule. For example, although *Asplenium ceterach* is potentially a long-lived species, to the extent that it could be placed in the long-term trend, it is short-lived in many of its urban habitats, and it was decided to undertake an assessment using the short-term trend on this basis.

For clonal taxa, there are significant difficulties when placing taxa in either the long-term or short-term trend, depending on whether lifespan is based on the ramet (the preferred measure following IUCN Guidelines) or the genet. In clonal plants a ramet usually consists of a shoot and a root and an associated rhizome or stolon which can potentially become independent from the rest of the clone. Ramet lifespan is hard to measure, and the point at which they become independent individuals may only be discernible once the older ramets have died, and even then, this may be far from obvious. Very few authors report the point in time at which a rhizome linking multiple emergences of above-ground organs becomes sufficiently senescent that it no longer provides a physiological link. In the case of tuberous orchids that generate at least one new tuber each year to replace its senescing predecessor, the genetic line continues but no somatic cells persist into the following year, thereby challenging definitions of 'ramet'. Genets of many rhizomatous sedges can form densely aggregated 'rings', or near monospecific stands, over extensive areas, and as such the stand might therefore be said to be very long-lived, even if the individual ramets are not. If a ramet is defined as the emergence and survival of an individual shoot and its associated rhizome/stolon, then many long-lived species could be classified as 'short-lived', but we have opted against such an approach.

Ramets are formed in different ways. For example, *Carex humilis* develops new ramets intravaginally (within the leaf sheaths of old ramets) and there are no rhizomes or stolons. Consequently, a ramet in this case is in effect synonymous with a graminoid tiller (Wikberg & Svensson, 2003). In *Cirsium dissectum* rosettes die after flowering, but generally plants reproduce vegetatively before this happens, so it is reported as long-lived (De Vere, 2007). Clonal propagation is the dominant form of reproduction for this taxon, with very low rates of seedling establishment. If one was to assess the lifespan of this species based solely on the death of a flowering rosette, then *C. dissectum* would be short-lived, but this would not adequately reflect the threat to the organism itself, or to an individual subpopulation, as such an assessment would not take into account the dynamics of ramet replacement, longevity of the connecting stem structures, vegetative mobility, or other regeneration strategies.

Many experiments in the literature focus on leaf and floral lifespan, rather than that of the individual. Publications sometimes refer to the lifespan of a perennial herbaceous species as 'long-lived', but this definition is often equated with an age of greater than three years. To further complicate matters, Thomas (2002) notes that most plants do not age in the "strict gerontological sense". He concludes that as a consequence of developmental and adaptive strategies which resist, avoid and pre-empt ageing, most long-lived plants can hardly be said to age at all in any sense recognisable from animals. Clearly, this presents difficulties when determining generational length for plants *sensu* IUCN Guidelines, most especially for clonal taxa.

For annual or biennial taxa, it is recommended that the half-life of the seed bank should be taken into account when assessing generation length for Criterion A (IUCN 2024). Seed longevity is generally categorised into either transient (viable for less than 1 year), short-term persistent (viable until at least the second germination season), or long-term persistent (viable until at least the sixth germination season); *e.g.* Thompson (2000); Walck *et al.* (2007). The persistence of seeds in the soil is the result of a combination of many different factors which include seed size and shape, the robustness of the seed casing, seed production and density, dormancy, predation, and moisture and nutrient availability. Species that produce very long-lived seeds could theoretically be included in the long-term trend category if there was evidence that they persisted below the surface for decades. However, the evidence for such extreme longevity in the wild (*i.e. in situ*, as opposed to *ex situ* conditions) is almost entirely lacking, and consequently we have grouped all annuals and biennials into the short-term trend category.

Due to an absence of information for many perennials, it was inevitable that expert opinion was required when allocating a taxon to either the short- or long-term trend. When no information concerning lifespan was available in the literature, our decision was largely based around an examination of known traits: perennation, life form (based on Raunkiaer, 1934, but further developed specifically for the British flora by Hill *et al.,* 2004), woodiness and clonality.

In broad terms, perennial taxa with a primary lifeform of mega-, meso- and microphanerophytes (*i.e.* trees and shrubs), or nanophanerophytes, were assigned to the long-term trend category, except for one taxon (*Atriplex portulacoides*) which has a published lifespan fitting with the short-term trend category (Decuyper *et al.,* 2014).

Perennial taxa with a primary lifeform of chamaephyte (low-growing shrubs) were usually assigned to the long-term trend. For some genera such as *Helianthemum*, *Saxifraga* and *Vaccinium*, published information concerning longevity for one, sometimes two species, was assumed to also apply to all other native taxa within those genera if they were all known to share similar traits. In a few cases, published research stated a lifespan that fell within our short-term trend category (*e.g. Chrysosplenium alternifolium*, *C. oppositifolium, Veronica fruticans*).

Perennial bulbous geophytes were assigned to the long-term trend, based on a literature review that concluded that, for most taxa within this category, the age of an individual cannot be determined with any accuracy. In the few papers that do attempt to age an individual, *e.g.* an ecological study of *Gagea serotina* (Remucal, 2001), the minimum age was estimated at 20-30 years, although the author noted that this lifespan is likely to have been greatly underestimated.

Perennial non-bulbous geophytes *i.e.* those which propagate via corms, tubers or rhizomes *e.g. Actaea spicata* (von Zeipel, 2007), *Anemone nemorosa* (Shirreffs, 1985), *Cypripedium calceolus* (Kull, 1999), *Menyanthes trifoliata* (Hewett, 1964), *Paris quadrifolia* (Jacquemyn *et al.,* 2008) were mainly assigned to the long-term trend. The only exceptions were those taxa within this category that behave as vegetatively propagating annuals, termed 'pseudo-annuals'. Following a review of the literature, and in particular work by Krumbiegel (2001), 12 such taxa (*Adoxa moschatellina*, *Arum italicum*, *A. maculatum*, *Cardamine bulbifera*, *Circaea alpina*, *C. lutetiana*, *Colchicum autumnale*, *Ficaria verna*, *Gladiolus illyricus*, *Lysimachia europaea*, *L. maritima*, *Stachys palustris*) were assigned to the short-term trend.

Perennial non-bulbous geophytes with little or no vegetative spread *e.g*. *Anacamptis morio*, *Dactylorhiza viridis*, *Neotinea ustulata*, *Ophrys apifera*, *O. sphegodes*, *Orchis anthropophora*, *O. mascula*, *Orobanche caryophyllea*, *Phelipanche purpurea* were assigned to the short-term trend, unless evidence in the published literature indicated considerable longevity, *e.g. Neottia ovata* (Tamm, 1991), *Lathraea squamaria* (Atkinson & Atkinson, 2020).

Perennial hemicryptophytes, *i.e.* herbaceous perennials which produce perennating buds at the soil surface, where the buds are protected by leaf or stem bases, comprise by far the most populous lifeform category. Where information about lifespan was available for one (often multiple) species within a genus, and all other species within that genus had the same traits (perennation, lifeform, clonality, *etc.*) and biogeography as the published lifespan, then these 'remainder' species were usually assigned to the same trend category (either short- or long-term), unless there was compelling evidence to the contrary. While this method to assess lifespan was far from ideal, the combination of similar traits/ecology supported by expert opinion was thought acceptable for the purposes of separating taxa into two broad time-period categories for an assessment of threat on Criterion A. Occasionally, two literature sources gave conflicting ages which placed the species into competing trend categories, *e.g. Centaurea scabiosa, Filipendula vulgaris, Geranium pratense, Oxyria digyna, Plantago media, Polygonatum odoratum, Primula veris, Pulsatilla vulgaris, Saussurea alpina, Silene acaulis, Succisa pratensis, Viola rupestris*. In such instances, the longer of the two lifespans was used.

In the case of perennial hydrophytes, calculating even a rough lifespan presents an almost insoluble problem. An extreme example is *Callitriche hermaphroditica*, in which the pollen tube can grow down within the filament into the pedicel to fertilise the female flower in the opposite leaf axil. If this happens to 100% of flowers, then all plants are clones produced by selfing (all ramets are identical). There are many other less extreme examples that fit within this lifespan conundrum. Unsurprisingly, there were few sources detailing precise (or even estimated) lifespans for perennial hydrophytes, and so expert opinion was used to compartmentalise taxa into short- or long-term trends, in combination with the literature available, and especially Schou *et al.* (2023).

At the end of this exercise, of the 1720 taxa assessed within Appendix 1, a total of 767 taxa were assigned to the long-term trend and 953 taxa to the short-term trend (see 'trends' column in Appendix 1).

4.2.3 *Methods used for assessing Area of Occupancy (AOO) trends*

Area of Occupancy (AOO) is defined as the area occupied by a taxon within its overall range and is determined by the scale at which the presence of a taxon is recorded. In recent years it has become commonplace to record plants to at least tetrad (a 2 × 2 km square of the Ordnance Survey National Grid (OSGB)) resolution, and the tetrad is recommended as an appropriate-sized unit for measuring AOO by IUCN (2024). However, as records for the 1930-1969 time period were very frequently only made at hectad scale as were, albeit to a much lesser extent, records for the 1987-1999 period, the calculation of AOO here uses hectad resolution, thus allowing meaningful comparisons to be made across all three time periods.

Several spatial and temporal biases are inherent in all biological recording datasets. For example, some areas are recorded more intensively because of their accessibility and/or the number of volunteers available. These biases are likely to change through time and, therefore, analysing trends for a given species is not straightforward (Pescott *et al.,* 2019). In recent years, however, statistical methods have been developed to account for spatial and temporal variation in recording effort, thereby making the results of trend analyses more robust.

Hill's (2012) method of '**fre**quency **sca**ling using **lo**cal occupancy' (Frescalo), used for this Red List, builds upon several earlier methods developed to examine distributional change using atlas data (Pescott *et al.*, 2019; Stroh *et al.,* 2023). Whilst the algorithm is not intrinsically tied to any particular spatio-temporal scale, it was designed with British and Irish atlas data in mind, and the assumptions underpinning the method are most likely to be met at the larger scales used in atlas mapping (*e.g.* multi-year/hectad). The method is based on two key assumptions. Firstly, within local areas (technically a type of weighted neighbourhood constructed at the scale of the analysis), and across all available data, species' local frequency curves reliably index true occupancy, even when recording effort is less than total. Secondly, the frequency with which the commonest species (known as 'benchmarks') in a local area are recorded can be used as an index of local recording effort. If these assumptions are reasonable relative to the available data, then the frequency with which local benchmarks are recorded in any given neighbourhood can be used to adjust the all-time local frequency of a species, which in turn accounts for varying recording effort across space and time (see Hill, 2012 and Pescott, 2025 for more detail). This method is often an improvement on simply counting grid squares, as it acknowledges the importance of spatio-temporal variation in recording effort as a confounder of true change. However, as with all quantification based on assumptions (including simple data tabulation), the extent to which the assumptions are met, or not met, within any given application require expert inspection and careful application (Boyd *et al.,* 2022, 2023).

As per the IUCN (2024) requirement to use trends covering timescales that are appropriate for a given species' longevity (as mentioned in section 4.2.1), a decision was made to use either the short- (1987–2019) or long-term (1930–2019) trend (Stroh *et al.,* 2023). Percent declines were based on linear changes in the Frescalo 'time factors' (relative frequencies) between the mid-point of the first and last date-classes for the relevant time period. These were based on the line ensemble methodology presented in Pescott *et al.* (2022), summarised as median change with its 5th and 95th percentiles. To assist with the inspection of each modelled trend, a 'model-based certainty' (MBC) estimate was derived for each species by dividing the absolute value of the mean of the slope distribution by its standard deviation (for further details see Stroh *et al.,* 2023, p. 18). In cases where the MBC was low (*i.e.* close to zero) and the associated modelled median trend was within 4% of an IUCN threat threshold, expert opinion was sought and sometimes resulted in the threat assessment being either upgraded or downgraded. Any revision to the modelled trend is documented in the 'notes' column in Appendix 1.

Frescalo trends were not used for species recorded in ≤15 hectads for an assessment period because these taxa are frequently likely to be fully censused at this scale, thereby invalidating the Frescalo assumption that overall variations in recording effort are relevant adjustments. For much the same reasons, trends for species present in fewer than or equal to 30 hectads were frequently also not used if confidence in the modelled trend was low.

For 29 exceptionally common taxa with widespread distributions (*e.g. Lolium perenne*, *Pteridium aquilinum*, *Sambucus nigra*), the Frescalo change statistic implied substantial decline over time. This is because the time factor metric, normally used to assess Frescalo trends, maps to predicted absolute occupancy in a non-linear fashion (Bijlsma, 2013; Pescott, 2025). Therefore, the same percent change in a time factor can map to different predicted occupancy changes depending on the local commonness or rarity of the taxon being assessed. Maps of predicted occupancy (*i.e.* the modelled probability that a taxon is actually present in a hectad) from Frescalo (following Bijlsma, 2013) were used to assess these scaling-dependencies for some widespread species where the time factor percent changes were considered exaggerated. This approach often, but not always, resulted in the Frescalo change outputs being rejected and revised, with revision based on the known distributions over time, predicted occupancy, and expert opinion. When changes to the modelled trend have been made, they have been documented in the 'notes' column in Appendix 1.

4.2.4 *Methods used for assessing Extent of Occurrence (EOO) trends*

Extent of Occurrence (EOO) is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all extant locations of a taxon. EOO is commonly referred to as a measure of range, although strictly speaking EOO measures the geographical spread of areas currently occupied by the taxon. A taxon with a large EOO is usually less likely to be adversely affected by a single threatening event than a taxon with a smaller EOO because the risk is spread more widely. However, calculating EOO is not simply a case of 'joining the dots' and calculating the area within the drawn boundary; indeed, arriving at an EOO can be particularly problematic in cases where a taxon has a highly disjunct or predominantly coastal distribution.

Two broad methods were tested for measuring EOO for this Red List. The first used the Minimum Convex Polygon (MCP), which is an algorithm that finds the smallest single convex polygon that contains all the points. This is akin to stretching an elastic band around a set of pins on a board. Two metrics for the MCP were produced; one measured the area of the MCP, while the other involved clipping the MCP to the GB coastline in order to determine the area of the MCP that covered land only (excepting *Zostera* spp.). The MCP can, however, be extremely sensitive to individual points, particularly extreme outliers, which in turn makes it less-than-ideal for determining changes in range between time periods.

The second method tested, and subsequently selected, for calculating EOO in this Red List, was alpha hull, suggested in the IUCN Red Listing guidelines as an alternative to the more standard Minimum Convex Polygon. Similar to the MCP, the alpha hull is an algorithm used to produce a convex hull based on a set of points. However, unlike the MCP, the hull need not encompass all points and may be composed of one or more polygons. The alpha hull includes a variable, ɑ (alpha), that specifies the extent to which outlying or isolated points are excluded from the final convex hull. As ɑ increases, the hull produced encompasses more of the points, approaching the MCP, until all points are enclosed in the hull. Conversely, as ɑ decreases, the hull will exclude the most isolated points until ɑ is so small that all points are excluded, and no hull is produced. The values at which these two extremes occur, and how the convex hull changes in between, are dependent upon the distribution of points geographically and the units with which the positions of the points in space are specified.

When alpha hulls are used to estimate the EOO, ɑ should be of sufficient magnitude for the convex hull to encompass the majority of points, excluding only the more remote or isolated points. As a result, the alpha hull is less sensitive to extreme outliers than the Minimum Convex Polygon. For this Red List, an ɑ value of 200,000 was used to fit hulls to the occurrence data in order to estimate the EOO. The locations in the occurrence data were specified using eastings and northings (metres) from the origin of the OSGB. A buffer of 5 km was added to the hull prior to measurement of the area to ensure that the hull covered the extent of all squares, rather than joining the central points of squares forming the boundary of the hull. In addition, a minor adjustment of the hulls was performed, using a GIS simplification function, aiming to slightly reduce their fine-scale complexity in order to make them easier to work with and store.

4.3 *Application of Criterion B*

This criterion identifies as threatened those taxa which have a restricted geographic range and meet at least two of the following three subcriteria; (a) populations severely fragmented or the taxon present in ≤10 locations, (b) populations or AOO/EOO showing a continuing decline, and/or (c) extreme fluctuations in range or population (Table 1). A location is defined by the IUCN (2024) as 'a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present'; and that in addition, 'the size of the location depends on the area covered by the threatening event'. A 'location' in this context has a specific meaning and is, therefore, not always synonymous with a 'site'. In some circumstances, as in Cheffings & Farrell (2005) and Stroh *et al.* (2014), a location is defined as a 'management unit', on the grounds that a change in management is assumed to be the most threatening event likely to be faced by a taxon. Hydrological units (such as linked drainage systems) are assumed to be single locations for aquatic plants, since a pollution event could affect the entire system. We have not used 'severe fragmentation' as an alternative risk factor to the number of locations for assessments, due to a paucity of information concerning population measures, including the minimum viable population size, for which information is lacking for the British flora.

The IUCN Guidelines (2024) note that in general terms the AOO for assessments based on Criterion B should be calculated as simply the total area of all tetrads occupied by the species. For this simple metric of AOO, the values would, by definition, be multiples of 4 km^2 (the area of one tetrad). However, this measure is very prone to changes in recorder effort over time and, therefore, any trends inferred from changes in the tetrad counts should be treated with caution and framed in the context of the associated changes in recording. The IUCN Guidelines also state that alternative modelling/inference approaches can be used to estimate AOO for Criterion B. The alpha hull AOO method we have implemented uses the alpha hull algorithm used for EOO (and recommended by IUCN for that purpose), but with a much smaller alpha value (one order of magnitude smaller than α used for the EOO alpha hulls) to construct hulls only around a set of points that are much more closely located. This is done in an attempt to estimate the portion of the geographic extent (as measured by EOO) that the species actually occupies, while trying to control for recorder effort spatially and over time. This estimate of AOO, although still affected by recording effort to some extent, is theoretically less sensitive to changes over time and space than simple tetrad counts. Whilst we consider this to be a more accurate measure of AOO for Criterion B to assist in an assessment of threat, an examination of the initial outputs showed that this approach did not work well for rare species. Consequently, for nationally rare (present in ≤15 hectads) and nationally scarce (present in ≤100 hectads) taxa which were known to be well-recorded in all time periods analysed, we calculated the AOO simply by counting the number of occupied tetrads, rather than referring to the modelled output.

4.4 *Application of Criterion C*

Criterion C considers the combination of small population size with similar risk factors to Criterion B. Population information was obtained from numerous sources, many of them unpublished.

4.5 *Application of Criterion D*

Criterion D identifies very small or geographically restricted populations. Population information was obtained as for Criterion C, and location information as for Criterion B. As well as basing an assessment of threat on population size, a taxon can also be assessed as threatened (VU D2) if it occurs in ≤20 km^2 and/or in 5 or fewer locations, but only if there is a plausible reason for supposing that it is also in danger of becoming CR, EX or RE within a very short time period, which the IUCN Guidelines imply as being within one or two generations. In several cases, a taxon potentially qualifying as VU D2 on the grounds of it being present in 5 or fewer locations was nevertheless assessed as LC due to its populations having been stable for many decades and with no obvious threat of it becoming CR, EX or RE within the permitted timeframe.

4.6 *Thresholds for Near Threatened*
IUCN do not provide quantitative thresholds for the category of Near Threatened (NT), but they state clearly that the taxon should be close to qualifying for the relevant Vulnerable category. Following consultation with Dr Andy Brown (our IUCN Authority), we adopted the following quantitative thresholds:

Criterion A	≥28% decline in AOO and/or EOO for the relevant short- or long-term trend
Criterion B	restricted geographic range meeting the requirements for threatened (EOO <20,000 km^2 and/or AOO <2,000 km^2), plus meeting one of the three subcriteria (either continued decline, ≤10 locations or extreme fluctuation)
Criterion D	≤1,500 mature individuals

It is important to note that the NT thresholds adopted here differ from those used for Cheffings & Farrell (2005). This is because those thresholds were considered to be insufficiently close to the equivalent VU thresholds to meet IUCN Guidelines. Previously, the NT threshold for Criterion A stipulated a ≥20% decline in AOO and/or EOO between the first and second atlas date classes; for Criterion B, presence in ≤30 locations and continuing decline; for Criterion D, ≤10,000 individuals.

4.7 *Appendices*
The 2005 *Red List* presented three tables: a 'Main List', which reported assessments of threat (including Data Deficient) for native, 'native-or-alien' and archaeophyte taxa; a 'Waiting List', which included taxa for which an assessment of threat could not be made due to inadequate distributional data, taxonomic uncertainties and/or uncertainty over status; and a 'Parking List', listing taxa that were excluded from the analysis largely due to reasons pertaining to research showing incontrovertible evidence that they should be placed at a lower rank than subspecies, or because they were considered to be neophytes. As mentioned in section 2.4, the 2005 *Red List* also largely excluded taxa within the three large apomictic genera, as well as some critical taxa for which there were insufficient distributional data available or where taxonomic issues were judged unresolved.

Appendix 1 in this new Red List is synonymous with the 'Main List' published in Cheffings & Farrell (2005), and it is important to note that we have based our analysis and subsequent results set out in section 5 on this appendix only. Appendices 2-5 contain apomictic or critical taxa within groups that were very largely not mapped in Stroh *et al.* (2023) but for which there were considered to be sufficient distributional data, published works and expert opinion for an assessment of threat to be made, and subsequently for potential priorities for conservation action to be identified by relevant organisations. All threat assessments for taxa included in Appendices 2-5 followed the same rigorous approach adopted for

Appendix 1. We have also included Waiting and Parking Lists, using the same criteria as Cheffings & Farrell (2005).

5 Results

5.1 *Summary of Red List assessments*

Of the 1720 taxa assessed using IUCN criteria and listed in Appendix 1, 26% are listed as threatened (*i.e.* one of Extinct in the Wild, Regionally Extinct, Critically Endangered, Endangered, or Vulnerable), 8% as Near Threatened, 65% as Least Concern and 1% as Data Deficient (Table 2). For the 2005 *Red List*, the results were, respectively, 23% threatened, 5% Near Threatened, 70% Least Concern, 2% Data Deficient. The location of threatened taxa in Britain, grouped by hectads, is shown in Fig. 1.

Table 2. Summary of numbers of taxa within each IUCN category of threat. * Includes *Heracleum sphondylium* subsp. *flavescens*, assessed as CR (PE) *i.e.* (Possibly Extinct), although more accurately it would be termed Possibly Regionally Extinct, as it is not an endemic taxon

IUCN Red List categories	**No. of taxa (no. of endemic taxa)**
Extinct (EX)	0 (0)
Extinct in the Wild (EW)	3 (2)
Regionally Extinct (RE)	22 (0)
Critically Endangered (CR)	55* (21)
Endangered (EN)	117 (22)
Vulnerable (VU)	261 (13)
Near Threatened (NT)	140 (5)
Least Concern (LC)	1097 (5)
Data Deficient (DD)	25 (1)
Total no. of taxa assessed	**1720 (69)**

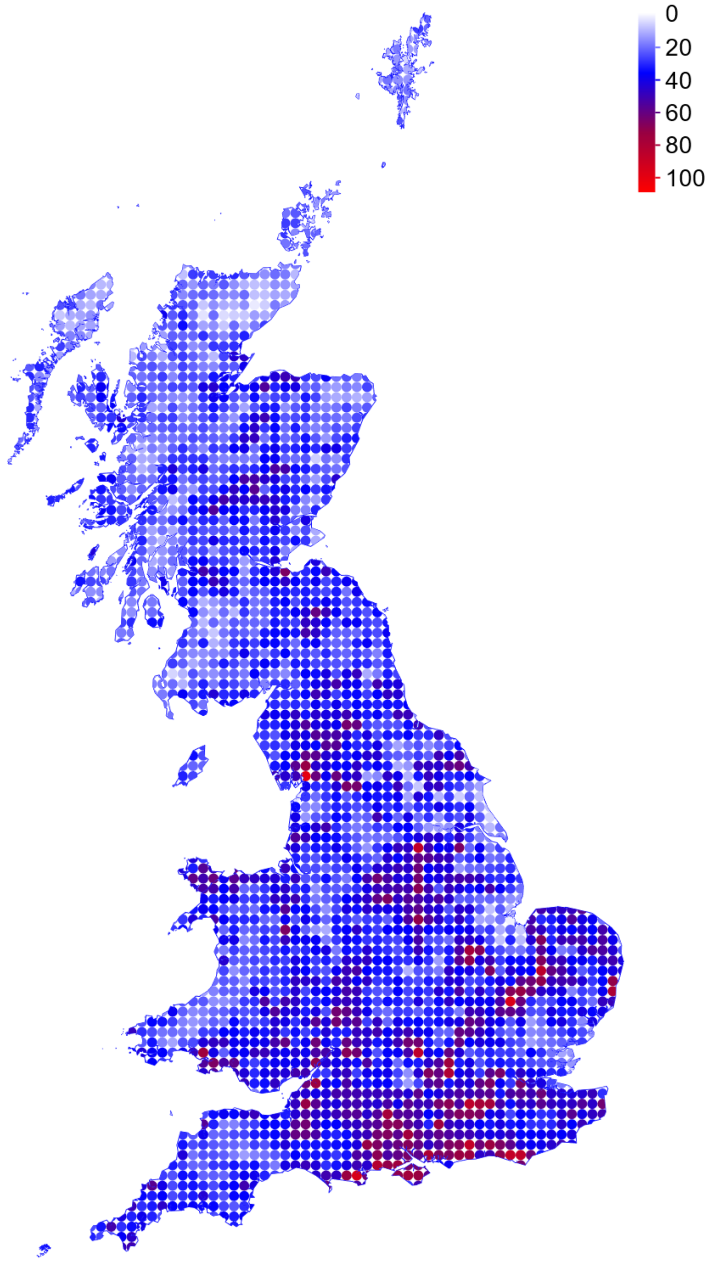

Figure 1. Heatmap showing the location of threatened taxa in Britain grouped by 10 km squares (hectads) for the time period 2000-2019. The continuous colour scale ranges from none or very few threatened taxa present in a hectad (white/pale blue) through to a maximum of 110 threatened taxa present (bright red). For example, the chalk belt of southern England contains a high number of threatened taxa per hectad, as do Anglesey in Wales and the Cairngorms region of Scotland, whereas there are relatively few threatened taxa present in the time period mapped for southwestern Scotland and hectads close to The Wash in eastern England

5.2 *Taxa with a higher threat status compared with the 2005 GB Red List*

When compared with Cheffings & Farrell (2005), 285 taxa are assessed as having a higher level of threat. Of these, 207 taxa previously assessed as LC are now assessed as NT (88), VU (106) or EN (13); 41 taxa previously assessed as NT are now assessed as VU (35), EN (6) or CR (1); 30 taxa previously assessed as VU are now either EN (26) or CR (4); 5 taxa previously assessed as EN are CR; 2 taxa assessed in 2005 as CR are now RE. In Appendix 1, the column titled 'Change from 2005 assessment' annotates changes for all taxa.

Several factors may have contributed to an increase in threat status since the publication of the 2005 *Red List*. For example, more accurate information concerning the number of individuals for some nationally rare species that have relatively stable distributions has sometimes resulted in an increased threat assessment *e.g. Cicerbita alpina, Homogyne alpina, Ranunculus reptans*. Revisions to the NT thresholds, and specifically those relating to Criterion B, have led to some taxa that were previously assessed as LC being now assessed as NT, including *Bartsia alpina, Calamagrostis purpurea, Carex atrata, C. chordorrhiza, C. norvegica, Eleocharis mamillata* subsp. *austriaca, Ononis reclinata, Primula scotica, Trinia glauca* and *Viola rupestris*.

It might be argued that under-recording has sometimes played a role in an increased threat assessment, especially for dynamic or inconspicuous taxa. However, botanical recorders have faced such issues for all three atlas projects, and the Frescalo model, used for the first time in a GB Red List here, attempts to correct for recorder effort over time. On a more general note, the Frescalo model used for an analysis of change is more sensitive than the previous model. Consequently, it is probable that for at least some taxa, the threat status might not have increased if Frescalo had been available for application to the 2005 List.

The assessments presented in Appendix 1 highlight many examples of historically widespread 'positive indicators' of semi-improved habitats that were previously assessed as LC for the 2005 Red List but are now assessed as threatened, and whose decline in distribution mirrors the degradation, destruction and increased fragmentation of suitable habitat. This is particularly true, though not exclusively so, for lowland regions, with many formerly widespread taxa having become increasingly confined to protected refugia. Examples of such indicator species that were formerly assessed as LC but are now assessed as threatened include *Betonica officinalis, Briza media, Caltha palustris, Campanula glomerata, C. rotundifolia, Cirsium acaule, Genista tinctoria, Helianthemum nummularium, Hydrocotyle vulgaris, Ononis repens, Parnassia palustris, Pedicularis palustris, Polygala vulgaris, Silaum silaus, Succisa pratensis, Thymus drucei* and *Valeriana dioica*.

Figure 2. *Parnassia palustris*. Image: Peter Stroh

Taxa of wetland (inclusive of marsh, fen, mire, bog) and aquatic environments, formerly assessed as LC but now assessed as threatened, include *Catabrosa aquatica, Cirsium dissectum, Eleocharis acicularis, Epipactis palustris, Helosciadium inundatum, Oenanthe aquatica, Potamogeton lucens* and *Triglochin palustris*. Arable taxa that were LC in 2005 but are now listed as threatened include *Chaenorhinum minus, Descurainia sophia, Lamium confertum, Legousia hybrida, Lysimachia foemina*, *Papaver dubium* and *Roemeria hispida*.

Figure 3. ***Epipactis palustris.*** **Image: Peter Stroh**

Figure 4. *Lysimacha foemina*. Image: Peter Stroh

A decline in distribution and/or range contraction for a small number of taxa with a higher level of threat can be plausibly linked, at least in part, to climate change *e.g. Juncus capitatus* and *Viola kitaibeliana* in southern Britain, and *Mertensia maritima, Sabulina rubella, S. stricta, Sagina nivalis, Saxifraga cernua* and *S. rivularis* in the north.

5.3 *Taxa with a lower threat status compared with the 2005 GB Red List*
When compared with Cheffings & Farrell (2005), 111 taxa are now assessed as having a lower threat status. Of these, 6 taxa previously assessed as CR are now assessed as EN (4) or VU (2); 36 taxa previously assessed as EN are now assessed as VU (20), NT (9) or LC (7); 42 taxa previously assessed as VU are now assessed as NT (15) or LC (27); 27 taxa previously assessed as NT are now assessed as LC. The column titled 'Change from 2005 assessment' in Appendix 1 annotates changes for all 111 taxa.

Several broad themes underlie a lower threat status than was published in 2005, perhaps the most notable being the requirement to conduct the assessments based on the longer of 10 years or 3 generations (IUCN 2024) and therefore the need to allocate species to either the short- or the long-term trend (periods used as a proxy for generation length; see section 4.2). When an assessment was based on the short-term trend, historical decline (*i.e.* pre-1987) could not be taken into account. Thus, a widespread taxon that experienced substantial losses in distribution during the period 1930-1986 but subsequently remained relatively stable, such that it failed to meet any of the thresholds for a threatened status, would have to be assessed as LC. Examples of taxa that fit this scenario included *Fumaria parviflora, Gentianella campestris* and *Silene otites*. Many other taxa assessed on their short-term trends have continued to decline, but at a lower rate than they did historically, to the extent that they now have a lower threat category than in the 2005 List *e.g. Galeopsis angustifolium*, *Scandix pecten-veneris* and *Turritis glabra*. It should be stressed that many of these formerly widespread taxa remain conservation-dependent, having become increasingly restricted to SSSIs and nature reserve 'refugia', or to land within agri-environment schemes where threats are reduced as a consequence of sensitive management options.

Figure 5. ***Scandix pecten-veneris.*** **Image: Peter Stroh**

Following substantial historical declines, some taxa have also become less threatened due to concerted conservation efforts in recent years *e.g. Cicendia* *filiformis, Crepis foetida, Liparis loeselii*. In addition, the short-term trend for several archaeophyte taxa was influenced by the deliberate sowing of new subpopulations via seed mixes, to the extent that they now have a reduced threat assessment *e.g. Glebionis segetum* (VU to LC).

For a few taxa, *e.g. Ajuga pyramidalis* and *Sibbaldia procumbens*, past decline may have been over-estimated and threat has been lowered following improved knowledge of their distribution. Some have also changed from NT to LC due to the revision of the Near Threatened Criterion D threshold which previously allowed a taxon with a population of <10,000 individuals to be assessed as NT, but with the limit now set at <1,500 individuals. Some taxa, however, seem to be genuinely increasing in their known range and distribution due to factors that include natural dispersal (*e.g.* wildfowl), greater resistance to herbicides, changes to arable practices and also unintentional dispersal by humans *e.g. Bromus secalinus, Filago germanica, Galium parisiense, Hypochaeris glabra* and *Lythrum hyssopifolia*.

Figure 6. *Bromus secalinus*. Image: Peter Stroh

It is possible that for some taxa with a lower threat status than previously, climate change has played a positive role in assisting the expansion or establishment of new subpopulations, and/or an expansion or consolidation of range following dispersal. Evidence to support this supposition is equivocal for taxa with a lower threat status in this Red List compared with 2005, but it is certainly the case that the orchids *Anacamptis pyramidalis*, *Dactylorhiza praetermissa* and *Ophrys apifera* and the ferns *Asplenium scolopendrium* and *Polystichum setiferum*, all assessed as LC in both GB Red Lists, have undergone remarkable range expansions in recent decades, presumably because milder winters have allowed them to survive further north and west (Walker *et al.,* 2024).

6 Ecological characteristics of threatened taxa

The results of analyses investigating threat categories in relation to broad habitats, Ellenberg indicator values and biogeographical distributions in Britain are presented here. Assignments of taxa to broad habitats and Ellenberg values are from Hill *et al.* (2004), and to biogeographical clusters from Preston *et al.* (2013). For broad habitats, some taxa are assigned in Hill *et al*. (2004) to more than one habitat (up to four); in such instances, they are attributed to all applicable broad habitats for the analysis. Note that trait values for 13% of all taxa assessed (25% of taxa assessed as CR, 14% EN, 7% VU, 10% NT, and 2% LC) included in this Red List were not available, and so these taxa were excluded from the analyses.

6.1 *Broad habitats*

The proportion of threatened or Near Threatened and Least Concern taxa across 16 broad habitats is shown in Fig. 7. Montane and calcareous grassland habitats, and to a lesser extent inland rock, support the highest proportion of threatened taxa, with threat frequently associated with rarity (edge of range, few and often relic locations, small population size, etc.) but compounded by recent land use changes, primarily the intensification or reduction of management, or by other pressures such as eutrophication, climate change and/or the spread of more competitive species.

Taxa associated with other broad habitats have been mainly impacted by the intensification of agricultural management via factors that include drainage, conversion to more agriculturally productive land use, long-term neglect, eutrophication and pollution. These factors have had a disproportionate impact in lowland regions, especially for broad habitats such as acid grassland and bracken, standing waters, and heathlands and bogs. Taxa associated with wetlands, running waters, and neutral grasslands and boundary habitats (*e.g.* road verges, hedgerows) have also been affected by such changes, although many taxa in such habitats are widespread and cosmopolitan, and thus the proportions of threatened species are lower. Numerous taxa associated with arable land have declined due to intensification (including increased use of herbicides and fertilisers, improved seed cleaning, more frequent cropping, etc.).

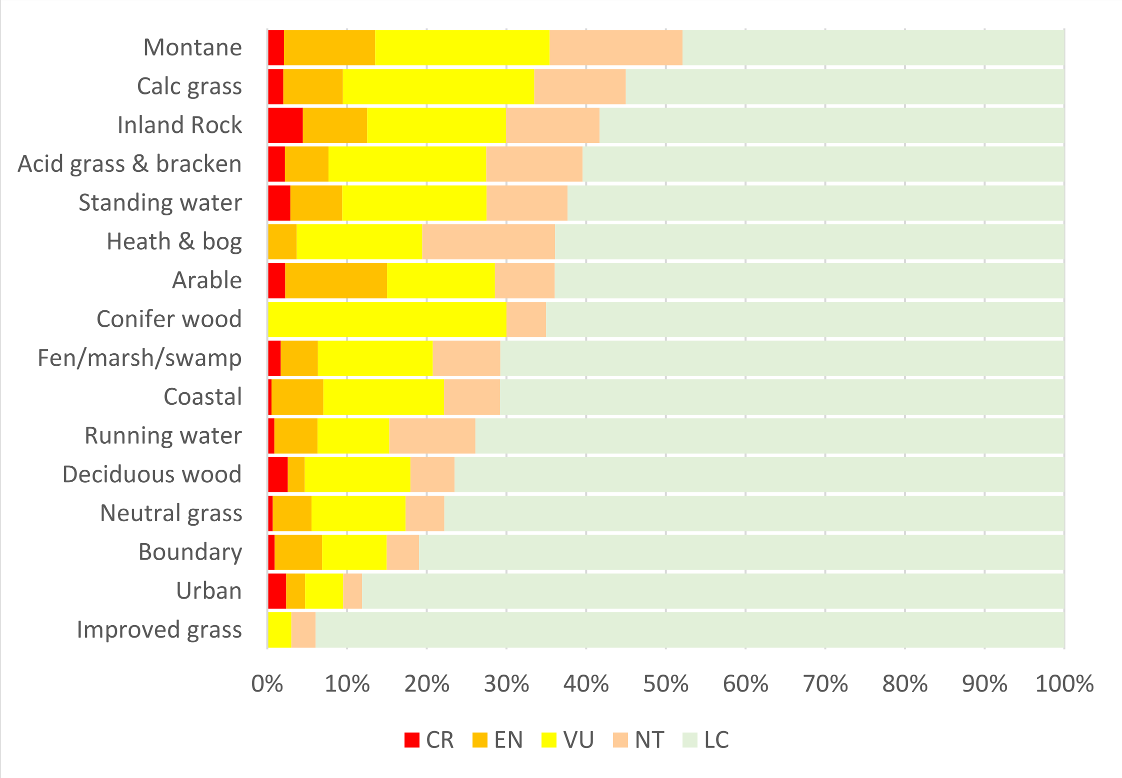

Figure 7. The threat categories of British vascular plants in relation to UK broad habitats. For each broad habitat the figures are expressed as the proportion of species assigned to each threat category. Note that some broad habitats included in Hill *et al.* (2004) have been combined (Acid Grassland & Bracken BH 8-9; Heath & Bog BH10 & BH12; Coastal BH18-23)

Woodlands and coastal habitats are possibly the broad habitats that have been least affected by human influences over recent decades and, as a result, have some of the lowest proportions of threatened species. However, each of these broad habitats has guilds of species that have declined due to specific pressures. For woodlands, factors include the loss of a cyclical coppicing regime, disease, overgrazing by deer, or destruction for development and infrastructure projects, and for coastal habitats, increased recreational disturbance, development, or more frequent storm surges and sea-level rise associated with climate change.

The broad habitats with the lowest proportions of threatened species were urban and improved grassland. In most cases the assignment of threat for taxa in these habitats is due to their threatened status in other habitats, for example arable archaeophytes that occur in urban habitats as neophytes.

6.2 *Ellenberg indicator values*

Values are available for most (87%) of the taxa included in Appendix 1 to indicate their preferences for light, moisture, soil reaction, soil fertility and salinity. These values, named after the German ecologist Heinz Ellenberg who pioneered this approach in Europe, place each taxon on an ordinal scale ranging from low (1) to high (9 or 12) and were derived for Britain via a meta-analysis of quadrat data (Hill *et al.* 2001, 2004). Threat categories are presented here in relation to British

Ellenberg values for light, moisture, pH (reaction) and soil fertility (Fig. 8).

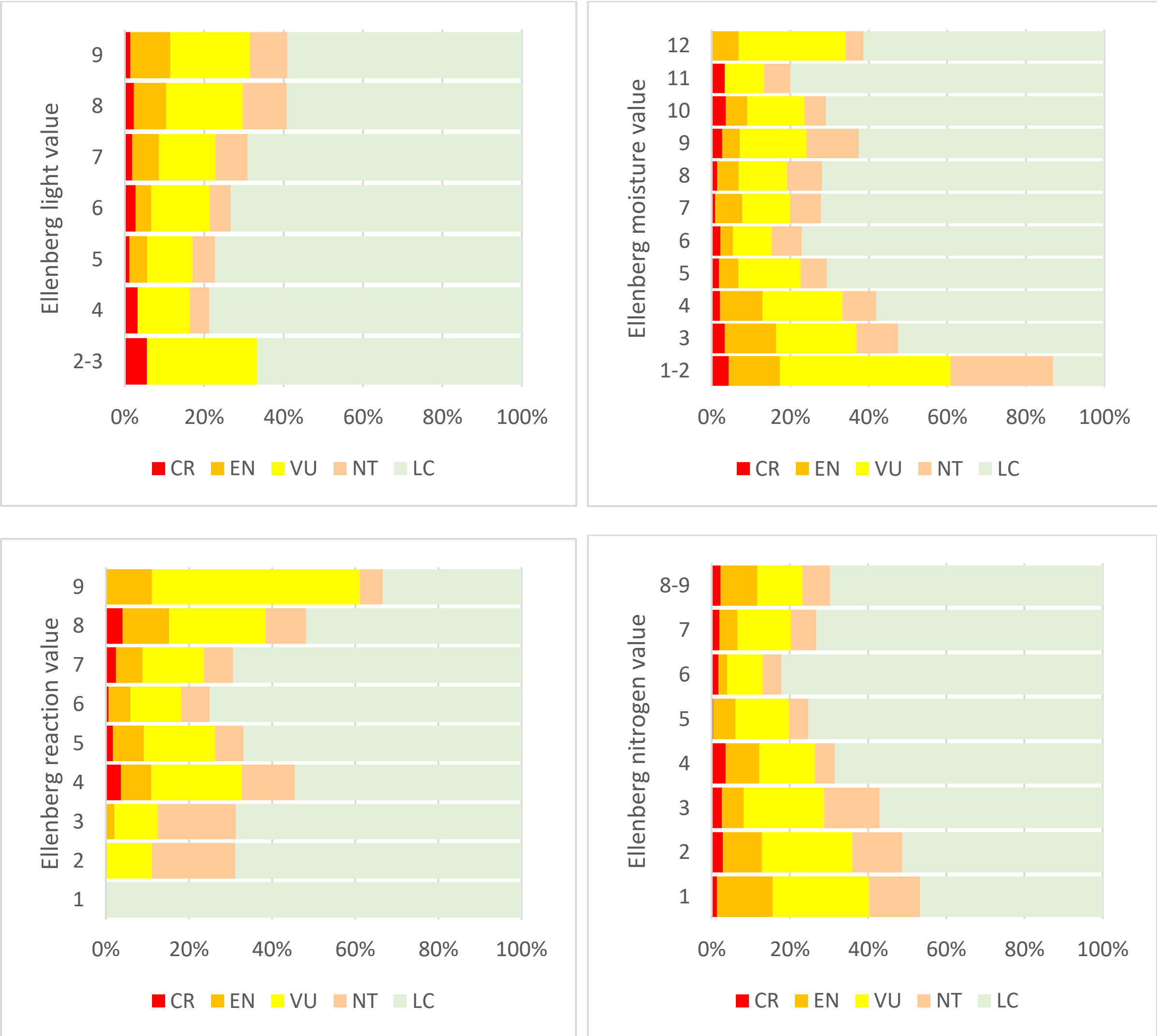

Figure 8. The threat categories of British vascular plants in relation to Ellenberg indicator values for light (L, top left), moisture (F, top right), reaction (R, bottom left) and soil fertility (N, bottom right). For each Ellenberg value the figures are expressed as the proportion of species assigned to each category. Note that some Ellenberg categories have no British species (*e.g.* L = 1, deep shade) or were combined due to low numbers of species

The relationship with light values is bimodal, with the highest proportions of threatened species associated with either deep shade (L2-3) or very open conditions (L8-9). As noted above, the woodland flora as a whole is generally less threatened, and this is reflected by the lowest proportion of threatened taxa being in L4-5, equating to the moderate shade of deciduous woodland. Taxa of the two extremes, deep shade (*e.g.* *Actaea spicata*, some *Epipactis* spp., *Neottia nidus-avis*, *Paris quadrifolia*) and very open conditions, are more susceptible to changes in management and grazing levels in woods, heathlands and grasslands over the last century.

The light and moisture values are somewhat correlated, with species of the most open habitats also being found in the driest habitats. Therefore, the drier habitats (F1-4) have greater proportions of threatened taxa than those associated with damper terrestrial habitats (*e.g.* neutral grasslands). However, plants of wetland and aquatic habitats (F >7) also have a higher proportion of threatened species, reflecting the greater pressures these habitats face, such as pollution, eutrophication and drainage.

The relationship between threat and soil pH (reaction values) shows plants of highly calcareous (R8-9) and acidic soils (R4-5) having the highest proportions of threatened species. This is not the case for taxa of extremely acid ground (R1-3), which are slightly less threatened. This possibly reflects the fact that many species of the most highly oligotrophic habitats, such as bogs and wet heaths, are still relatively widespread in the north and west of Britain.

The relationship between threat and soil fertility was also strongly bimodal, with plants of the least fertile soils (N1-4) being the most threatened as a result of the improvement of infertile, species-rich habitats. Interestingly, plants of the most fertile soils (N8-9) are also highly threatened. Contained in the latter are a small suite of species, including many 'chenopods', that were formerly associated with highly fertile soils on agricultural land and also in towns and villages, in places such as middens and dung heaps, that have now largely disappeared from contemporary landscapes. Modern cultivation methods have also likely contributed to the decline or loss of many such species.

6.3 *Biogeography*

Preston *et al.* (2013) analysed the biogeography of the British flora using hectad distribution data to identify distinct clusters of taxa displaying similar distribution patterns. All native or doubtfully native (*i.e.* 'native-or-alien') British taxa (but not archaeophytes) were assigned to these clusters. The 20 clusters identified ranged from a *Romulea columnae* cluster in south-west Britain, most famously found on the Lizard Peninsula and Isles of Scilly in Cornwall, to a montane *Carex atrata* cluster, restricted to base-rich crags on mountains in Scotland, north Wales and northern England. Table 3 gives a summary of each cluster, while Fig. 9 shows the proportion of threatened, Near Threatened and Least Concern taxa falling within each cluster. More detail about the composition of the clusters can be found in Preston *et al.* (2013).

As one might expect, the clusters with the highest proportion of threatened species are those with the most restricted distributions in Britain, often because they are at the limits of their climatic ranges and/or because their associated geology is rare. These include the *Hippocrepis comosa* cluster, which is restricted to calcareous soils in lowland Britain, and its upland counterpart, the *Minuartia verna* cluster, which is centred on the hard (Carboniferous) limestones of northern England and north Wales. The *Carex atrata* cluster has the highest concentration of rare montane species in Britain, many of which are at the southern edges of their European range, while the *Romulea columnae* cluster has the highest concentration of southerly-distributed rarities. The *Medicago sativa* cluster, on the other hand, has a very high

Table 3. Biogeographical clusters in Britain. See Preston *et al.* (2013) for a detailed description of each cluster. * now *Lysimachia maritima*; ** now *Sabulina verna*

Cluster	Description
Romulea columnae	Restricted to SW Britain including The Lizard Peninsula, Isles of Scilly and the New Forest.
Crithmum maritimum	Coastal regions of SW and W Britain
Clematis vitalba	Throughout southern Britain
Hippocrepis comosa	Restricted to chalk and limestone regions in England
Medicago sativa	Sandy soils in East Anglia, mainly Breckland
Limonium vulgare	Soft coasts, especially saltmarshes, in the southern half of Britian
Oenanthe crocata	South-west England and Wales
Tamus communis	Widespread in lowland England and Wales; mainly woodland species
Lemna trisulca	The wetland equivalent of the *Tamus communis* cluster with a similar overall distribution
Epilobium hirsutum	Lowlands throughout Britain
Chaerophyllum temulum	Like the *Epilobium hirsutum* cluster but rare in western Britian
Stachys sylvatica	Like the *Epilobium hirsutum* cluster but with more species with ubiquitous ranges
Urtica dioica	The cluster with the largest number of species, many of which are ubiquitous and occur throughout Britain
*Glaux maritima**	A coastal cluster comprising species with ubiquitous ranges
Calluna vulgaris	A widespread cluster of plants of acid soils most frequent in N and W Britain
*Minuartia verna***	A cluster of species largely restricted to the Craven limestones in Derbyshire, Yorkshire and Lancashire
Alchemilla glabra	A widespread upland cluster occurring throughout Britain
Selaginella selaginoides	A westerly upland cluster
Alchemilla alpina	A montane cluster occurring in Scotland, north Wales and northern England
Carex atrata	A cluster restricted to base-rich crags on mountains in Scotland, north Wales and northern England

proportion of 'continental' species that are rare in Britain and mainly confined to the Breckland region of East Anglia. In contrast, the high proportion of threatened species in the *Lemna trisulca* cluster presumably reflects the significant declines of many widespread aquatic species in the face of eutrophication, deterioration of water quality and other pressures.

Some of the most widespread clusters, including the coastal *Glaux maritima* cluster and the ubiquitous *Epilobium hirsutum*, *Stachys sylvatica* and *Urtica dioica* clusters, had the lowest proportions of threatened species, reflecting the dominance of common species.

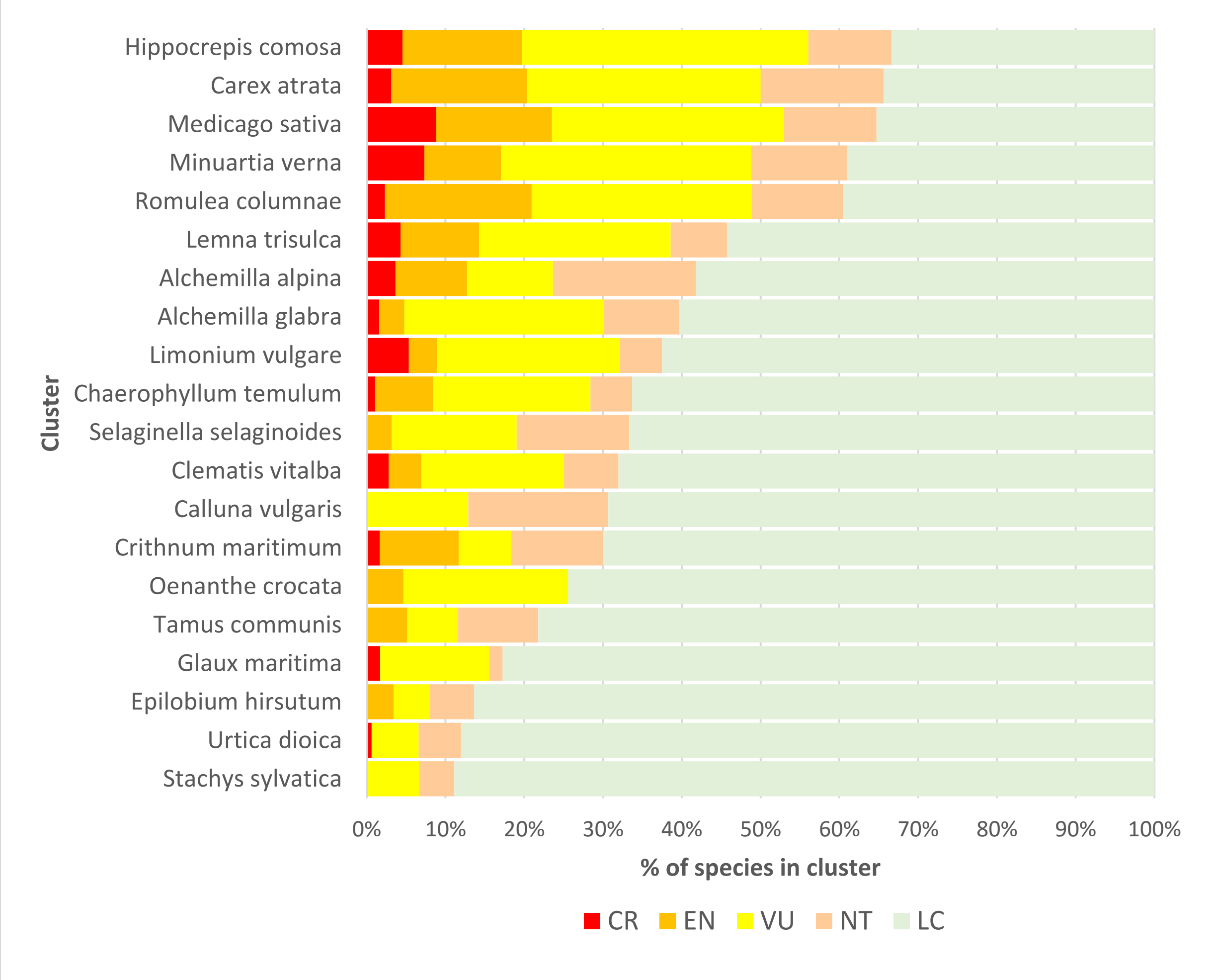

Figure 9. Biogeographic clusters of vascular plants in Britain in relation to threat categories. For each cluster the figures are expressed as the proportion of species assigned to each threat category

6.4 *Taxa reaching their absolute northern or southern European range limits*

Based primarily on information supplied in Preston (2007; but see also section 7.1.10), a total of 256 native or archaeophyte taxa (16% of all taxa listed in Appendix 1, excluding endemics) are found at their absolute northern or southern European range limits in GB, with 220 taxa (86%) at their northern limits, and 36 (14%) at their southern limits. Of these, 70 taxa are assessed as threatened (*i.e*. EX, EW, RE, CR, EN, VU), of which 58 are associated with northern limits, and 12 with southern limits. Table 4 provides more information about range limits and threat categories, and a column titled 'European edge of range' in Appendix 1 gives range limits for all these taxa.

There is a slightly greater proportion of threatened taxa associated with southern range limits (33%) in comparison with those associated with northern range limits (26%), albeit the sample size for the former is much smaller. Ten of the 12 threatened taxa at their southern range limits (*Arenaria norvegica* subsp. *norvegica*, *Artemisia norvegica*, *Diapensia lapponica*, *Erigeron borealis*, *Koenigia islandica*,

Table 4. **Summary of the number of taxa (excluding endemic taxa) present in GB that are found at their absolute northern (N) and southern (S) European limits between latitudinal bands N_1 (45°N and 50°N), N_2 (50°N and 55°N); N_3 (55°N and 60°N), N_4 (60°N and 65°N), S_1 (45°N and 50°N), S_2 (50°N and 55°N), S_3 (55°N and 60°N).**

IUCN Red List categories	N_1	N_2	N_3	N_4	S_1	S_2	S_3	Total
Extinct (EX)								**0**
Extinct in the Wild (EW)								**0**
Regionally Extinct (RE)		2						**2**
Critically Endangered (CR)	1	4	1					**6**
Endangered (EN)		12	4			2	3	**21**
Vulnerable (VU)		23	10	1		1	6	**41**
Near Threatened (NT)	1	13	3	1		3	2	**23**
Least Concern (LC)		67	69	7	1	14	4	**162**
Data Deficient (DD)			1					**1**
Total no. of taxa	**2**	**121**	**88**	**9**	**1**	**20**	**15**	**256**

Sabulina rubella, *Sagina nivalis*, *Salix lanata*, *Saxifraga cespitosa*, *S. rivularis*) are nationally rare (≤15 hectads), whilst the remaining two (*Mertensia maritima*, *Salix myrsinites*) are nationally scarce (≤100 hectads), occurring in 74 and 44 hectads respectively since 2000. All apart from *M. maritima* have a strong association with Montane broad habitats and/or Inland rock (such as cliffs or screes). All apart from *Saxifraga cespitosa* and *S. rivularis* are light-loving plants (Ellenberg L ≥8), and all except *Salix lanata* and *M. maritima* have a preference for highly infertile microsites (Ellenberg N ≤2) with no or very low competition (Hill *et al.* 2004).

Threats facing the majority of these taxa found at their southern limits are, at least in part, linked to the symptoms of climate change, either due to reduced snow cover and the reduction of open ground via vegetation encroachment, and/or the increased frequency and severity of spring and summer droughts. These factors have the potential to result in the total loss of suitable climate space for arctic-alpine taxa at the southern edge of their range.

At least one species, *Mertensia maritima*, appears to be experiencing a 'range shift' in distribution, with declines linked to increased storm damage and also higher winter temperatures that could inhibit seed production (*e.g.* Skarpaas & Stabbetorp, 2003). It is probable that climate change is also negatively affecting the recruitment and/or survival of seedlings for many of the montane edge-of-range species listed above (*e.g.* Orsenigo *et al.,* 2015). Overgrazing presents a current threat to subpopulations of *Salix myrsinites* and *S. lanata* and conversely, for taxa that require bare, open areas, increased levels of atmospheric nitrogen deposition help to facilitate the encroachment of competitive species which in turn leads to a reduction in the number and extent of suitably open niches.

Figure 10. *Artemisia norvegica*. Image: Simon Harrap

6.5 *Selected examples of applying IUCN threat criteria*

6.5.1 *Critically Endangered (CR)*

Ranunculus reptans (Creeping Spearwort)

This creeping, prostrate perennial herb of stony lake shores has always been a rare species in Britain, and was previously assessed as VU in the 2005 *Red List* based on subcriterion D2 *i.e.* occurring in 5 or fewer locations, and with a plausible future threat that could drive the taxon to Critically Endangered or Extinct within a short period of time (usually interpreted as one or two generations).

Figure 11. *Ranunculus reptans*. Image: Richard Lansdown

Recent comprehensive surveys by Lansdown (2024) have found that *R. reptans* occurs in Britain at three locations; as two patches on the southern margin of Loch of Strathbeg (North Aberdeenshire) with a combined area of *c.*14 m^2, a single patch on the margin of Loch Awe (Argyllshire) covering approximately 4 m^2, and patches in at least two areas on Ullswater (Westmorland), one of which covers more than 25 m^2 but is mixed throughout with plants intermediate morphologically to *R. flammula*.

Determining threat based on population trends is problematic, firstly because of its similarity, and potential misidentification with, the relatively widespread hybrid between *R. reptans* and *R. flammula* (*R.* × *levenensis*), which is itself capable of forming persistent populations and can be present in the absence of both parents, and secondly because some historical subpopulations seem to have been transient in nature (and possibly lost through hybridisation with *R. flammula*). Consequently, there is a lack of confidence in the data to assess population size reduction (Criterion

A) and changes in geographic range and/or decline (Criteria B and C). However, we do know that it has a very restricted geographic range, being present in only 3 locations, and so it would meet the qualifying criteria for NT on Criterion B. Information is available about population size, and although counting the number of mature 'individuals' is challenging due to its stoloniferous creeping growth form, there would appear to be *c.*5 'patches' in total. We have interpreted this number as meeting the threshold for CR on Criterion D, a category reserved for taxa with a very small or restricted population size. It is probable that the taxon still also qualifies as VU on Criterion D2; threats to the extant populations were not specified previously, but could be linked to future hybridisation, or to a major pollution event resulting in a rapid deterioration in water quality.

6.5.2 *Endangered (EN)*
Gentiana nivalis (Alpine Gentian)
This stunning bright-blue annual or occasionally biennial herb of open, species-rich montane vegetation was assessed by Cheffings & Farrell (2005) as NT based on a population estimate of *c.*5,000 individuals, and also a decline of greater than 20% in AOO since the first atlas recording period (1930-1969). *G. nivalis* was known at the start of the current recording period from 5 locations in Britain. Four of these were within the Ben Lawers range. At the fifth location (Caenlochan), up to 200 plants were recorded in the 1990s, but only a single individual was found in 2017 and 2020, and targeted searches since then (including two separate surveys in 2024) have failed to find any individuals.

Figure 12. *Gentiana nivalis* (blue flowers) growing with *Thymus* sp. (pink flowers). Image: Peter Stroh

Subpopulations at Ben Lawers (excluding the main subpopulation below the summit at the base of mica-schist cliffs, scree and sloping turf) were censused recently (Donaghy, 2021), with a total of 140 *G. nivalis* plants recorded. This number was thought to be low but perhaps not abnormal for an annual species when compared to past results from surveys in 1996 and 2012, and bearing in mind that numbers can fluctuate dramatically *e.g.* 343 and 7 individuals across the same area surveyed in 2015 and 2018 respectively. However, in 2021 no plants were found at the sites of three historically known subpopulations, and whilst the main subpopulation is estimated to support 1,000-3,000 individuals in 'good' years, very few plants were present in 2024.

Threat assessments for annual/biennial taxa are challenging. However, taking a precautionary approach for this nationally rare species, and given an estimated overall population of fewer than 2,500 individuals in most years, in combination with a potential recent decline in numbers/subpopulations/locations and with extreme year-to-year fluctuations in numbers, *G. nivalis* has been assessed as EN on Criterion C (small population size and decline) and also Criterion B, having a very restricted geographic range, 5 locations or fewer, continuing decline and extreme fluctuation.

6.5.3 *Vulnerable (VU)*

Campanula rotundifolia (Harebell)

This delicate perennial herb of infertile grasslands is found throughout Britain and is a welcome sight for field botanists in the summer months, albeit one that is not taken for granted, given that, especially in the lowlands of Britain, it has become increasingly associated with protected areas. Through habitat destruction or neglect and subsequent successional changes, many subpopulations were lost during the 20th century. Research in recent years (*e.g.* Maskell et al., 2010) also suggests that some species, including *C. rotundifolia*, may have declined as a result of acidification correlated with increased levels of nitrogen deposition.

Figure 13. *Campanula rotundifolia.* Image: Peter Stroh

The analysis of trends for the 2005 *Red List* detected a decline in AOO for *C. rotundifolia*, but not to the extent that it qualified as threatened or NT. However, the results presented here, using a more sensitive model than previous analyses, and taking into account a further two decades of data, reveal a long-term AOO trend of -44%, thus meeting the threshold for VU on Criterion A. Other wide-ranging but increasingly uncommon species associated with infertile grasslands previously assessed as LC in 2005, such as *Briza media*, *Helianthemum nummularium* and *Succisa pratensis*, have also been shown to have suffered similar long-term declines, and are now assessed as threatened for this Red List based on the AOO trend.

6.5.4 *Near Threatened (NT)*

Liparis loeselii (Fen Orchid)

The diminutive, nationally rare *Liparis loeselii* is now restricted to two regions of Britain; in East Anglia, it is found in a few species-rich fens on infertile soils, mainly old peat cuttings, whilst along the South Wales coast it grows in damp dune-slacks subject to winter flooding. It was until 1987 also found in dune-slacks at Braunton Burrows in North Devon.

Figure 14. *Liparis loeselii*. Image: Paul Sterry

Liparis loeselii was assessed as EN on Criteria A and C for the 2005 *Red List* based on a substantial decline in distribution during the 20th century, and also the small number of individuals present within each surviving subpopulation. Since then, a significant amount of conservation work has resulted in the stabilisation of extant locations (totalling 4 in England, including 2 with multiple subpopulations, and 3 in Wales), with 3 of the 4 England locations far exceeding 1,000 mature individuals each year from 2016 to 2024 (Tim Pankhurst, pers. comm.), and one of the Wales locations (Kenfig Dunes) supporting over 1,000 plants in 5 of the past 10 years (with a maximum of *c.*4,250 in 2019), with a mean of *c.*1,200 individuals over the past decade. The population in Britain is currently greater than 10,000 individuals. This means that it no longer qualifies as threatened or NT on Criteria A or C. The very restricted geographic range (based on AOO) combined with the small number of locations would potentially qualify *L. loeselii* for a threatened status on Criterion B. Some decline in numbers has been noted at two locations (Catfield and Kenfig) in recent years, the former due to acidification and succession to *Sphagnum*-dominated vegetation, and the latter a result of winter flooding becoming extended into the spring and summer months. Management works are in place to address the situation at Catfield. If prolonged flooding into the summer months at Kenfig becomes an increasingly regular event, it has the potential to reduce the number of individuals, and so the situation here requires close monitoring. As a result of the prolonged flooding noted above, and perhaps other as yet unknown factors, there is evidence of a fluctuation in the number of individuals recorded at Kenfig, one of the three locations in Wales, over the past 6 years (Julian Woodman, pers. comm.), but not yet to the extent that it meets the IUCN Guidelines for decline or 'extreme fluctuation'. Based on the current evidence, *L. loeselii* is assessed as NT on Criterion B (meeting one of the three subcriteria, *i.e.* number of locations), but would qualify as VU on the same criterion if monitoring at Kenfig in future years shows continuing decline and a deterioration in habitat quality/the suitable niche.

This positive revision to its threat status is a result of targeted conservation actions arising from a combination of scientific research, *ex situ* and *in situ* experimentation, regular monitoring and the commitment and knowledge of staff and volunteers from many different organisations. *Liparis loeselii* remains a conservation dependent species. The challenge now is to ensure that this species thrives in its current locations through ongoing targeted management, and that with greater understanding of its ecological niche we can enable this orchid to disperse naturally into new (and former) sites.

6.5.5 *Least Concern (LC)*

Gentianella campestris (Field Gentian)

An assessment of LC for this annual or occasionally biennial species of open, base-rich and nutrient-poor grasslands will come as a surprise to many British botanists. It was assessed as VU (under Criterion A) in the 2005 *Red List* due to a decline in distribution of greater than 30% across its range since fieldwork took place for the first atlas (1930-1969). *Gentianella campestris* was selected as the cover species for the 2005 publication to highlight the plight of many such 'widespread decliners'.

Utilising IUCN Guidelines for the first time to evaluate the British flora, its assessment as VU was emblematic of how changes to grazing management, most notably undergrazing in the lowlands, and habitat destruction, had resulted in the decline of this and so many other species of semi-natural, nutrient-poor habitats across our landscapes during the 20th century.

Figure 15. ***Gentianella campestris*****. Image: Bob Gibbons**

Now, however, following IUCN Guidelines, and assessing the species on the basis of its short-term trend (see section 4.2), the substantial pre-1987 decline detected by the 2005 *Red List* is no longer relevant to its assessment for this new Red List. While trends demonstrate that it has continued to decline since 1987 (AOO

-22%), the magnitude of any losses across the relevant time period are not great enough for it to meet the relevant threatened or NT thresholds for Criterion A. It also fails to qualify under Criterion B, as it exceeds the thresholds for the number of locations and restricted geographic range. Although *G. campestris* has never been censused in full across its entire British range, it is highly likely that the population greatly exceeds the thresholds for Criterion C (10,000 individuals) – see, for example, the series of stratified random surveys published in Walker *et al.* (2017) – and it certainly exceeds those for Criterion D (1,000 individuals).

Gentianella campestris is, therefore, assessed as LC despite now being so much more localised than it once was, and especially across much of the lowlands of southern England and southern Wales where it has become increasingly dependent on conservation management within nature reserves and SSSIs.

7 Explanation of the GB Red List

7.1 *Description of columns*

7.1.1 *Taxon name*

Scientific names follow those used in *Plant Atlas 2020* (Stroh *et al.* 2023) unless otherwise stated. There are several subspecies which were not mapped in the *Plant Atlas*, and for these we have generally followed the names and taxonomy given in *New Flora of the British Isles* (Stace, 2019). Taxonomy for the *Dryopteris affinis* segregates (Appendix 2) follows Sell & Murrell's (2018) treatment and includes several novel taxa described subsequently at specific level as recommended by them. *Hieracium* (Appendix 3) taxonomy follows Sell & Murrell (2006) with updates in McCosh & Rich (2018), and taxa within the *Limonium binervosum* aggregate (Appendix 4) follows Sell & Murrell (2018). *Taraxacum* (Appendix 5) taxonomy follows Richards (2021), but with the addition of six species added to the British list subsequently: *Taraxacum acrifolium, T. discretum, T. intermedium, T. johnstonianum, T. lambinonii* and *T. zevenbergii***.**

7.1.2 *Vernacular name*

Vernacular (common) names broadly follow those used in the 4th Edition of Stace (2019) for taxa listed in Appendix 1. Those in Appendices 2-5 follow the relevant authority *i.e.* Sell & Murrell (2018) for *Dryopteris affinis* segregates and *Limonium binervosum* segregates, Sell & Murrell (2006) and McCosh & Rich (2018) for *Hieracium*, and Sell & Murrell (2006) for *Taraxacum*. For the purposes of this Red List, those *Taraxacum* species not included in Sell & Murrell (2006) have had vernacular names freshly coined for them by A.J. Richards and S.J. Leach.

7.1.3 *Threat category*

The IUCN categories are as defined in *Guidelines for Using the IUCN Red List Categories and Criteria: Version 16* (IUCN 2024).

EXTINCT (EX)

A taxon is EX when there is no reasonable doubt that the last individual across its known global range has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, conducted at appropriate times throughout its historic range have failed to record an individual. Surveys should be enacted over a time frame appropriate to the taxon's life cycles and life form.

REGIONALLY EXTINCT (RE)
This category applies to a taxon that is extinct within Great Britain (*i.e*. the scope of this List) based on the EX criteria above but remains extant elsewhere within its known global native range.

EXTINCT IN THE WILD (EW)
A taxon is EW when it is known only to survive in cultivation or as a naturalised population (or subpopulations) well outside the historical native range. A taxon is presumed EW when exhaustive surveys in known and/or expected habitat, conducted at appropriate times across its historic range have failed to record an individual. Surveys should be enacted over a time frame appropriate to the taxon's life cycle and life form.

CRITICALLY ENDANGERED (CR)
A taxon is CR when the best available evidence indicates that it meets any of the Criteria A to D for CR, and it is therefore considered to be facing an extremely high risk of extinction in the wild. The tag of **'Possibly Extinct' (PE)** is included within the CR threat category. This descriptor identifies taxa assessed as CR that are, on the balance of evidence, likely to be extinct, but for which there is a small chance that they may remain extant but undetected. Note that PE is a tag, and not a formal Red List category.

ENDANGERED (EN)
A taxon is EN when the best available evidence indicates that it meets any of the Criteria A to D for Endangered, and it is therefore considered to be facing a very high risk of extinction in the wild.

VULNERABLE (VU)
A taxon is VU when the best available evidence indicates that it meets any of the Criteria A to D for VU, and it is therefore considered to be facing a high risk of extinction in the wild.

NEAR THREATENED (NT)
A taxon is NT when it has been evaluated against the Criteria but does not qualify for CR, EN or VU now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

LEAST CONCERN (LC)
A taxon is LC when it has been evaluated against all the criteria and does not qualify for CR, EN, VU or NT. Widespread and abundant taxa are often included in this category. However, some uncommon taxa that experienced substantial declines historically (*i.e*. pre-1987) are also included here if they were assessed on their

short-term trend (*i.e*. post-1986) and no longer qualified as threatened or NT on any of the criteria for the relevant time period (see section 4 for more details).

DATA DEFICIENT (DD)
A taxon is DD when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but for which appropriate data on abundance and/or distribution are lacking or insufficient to support a threat assessment. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.

NOT EVALUATED (NE)
A taxon is NE when it has not yet been evaluated against the criteria. There are no NE taxa in this Red List. However, taxa in the Waiting and Parking Lists (see section 9) are, in effect, 'not evaluated' taxa, in that they were considered for evaluation, but then excluded for any of the reasons specified in section 9.

7.1.4 *Threat Criteria*
See section 4.1 for details of the criteria used for an assessment of threat.

7.1.5 *Status*
The 'native', 'native-or-alien', or 'archaeophyte' status of a taxon follows Stroh *et al.* (2023). The status of a taxon in this context refers to GB as a whole (inclusive of England, Scotland, Wales), but such status may not apply to every geographical region or every record. For example, while *Acer campestre* is native across a large part of Great Britain, and accordingly in this Red List is assigned native status, it is mapped in Stroh *et al.* (2023) as 'alien' in Scotland and parts of south-west England and west Wales. Definitions of the terms 'native', 'native-or-alien' and 'archaeophyte' are provided in section 2.3.

7.1.6 *Trend*
This column shows which trend (short-term or long-term) was used for an assessment of threat (population reduction) using Criterion A. A fuller explanation of how taxa were assigned to one or other of the two trend categories can be found in section 4.2.1.

7.1.7 *Nationally rare/scarce*
In Britain, nationally rare taxa are those recorded from 15 or fewer hectads; nationally scarce taxa are present in 16-100 hectads. This Red List adopts the latest revision of the list of nationally rare and scarce taxa found in the online version of Stroh *et al.* (2023).

7.1.8 *Endemics and near endemics*
An endemic taxon is one for which the entire native global range lies within Great Britain. If its native range also includes Northern Ireland, the Republic of Ireland, the Channel Islands and/or the Isle of Man, then it is listed as a 'near endemic'.

7.1.9 *International responsibility*
Cheffings & Farrell (2005) attempted to estimate whether our area held a significant (taken to mean >25%) proportion of the European distribution for each taxon assessed by using the UTM 50 × 50 km grid (used in *Atlas Florae Europaeae* and others), and then estimating the proportion of that total found here. Updating this list using data collected and published for Europe since the publication of the last GB Red List would have been a significant undertaking and presented several fundamental issues, not least the problem of uneven sampling across Europe this century, the scale of sampling, and issues relating to the native/alien range. We have therefore used the estimates published in the previous GB *Red List*, and also included the large number of near endemic and endemic apomictic taxa not previously Red Listed in GB. The conclusions of whether GB holds an internationally important population of a taxon are presented as follows:

Yes	We are certain that GB holds more than 25% of the European population
Probably	We are fairly sure that GB holds more than 25% of the European population
Possibly	There is a reasonable chance that GB holds more than 25% of the European population

7.1.10 *European edge of range*
This column presents research published by Preston (2007) that lists native taxa that are found at the absolute northern and southern limits of their European distributions in Great Britain. Preston (2007) segregates the northern (N) and southern (S) European limit of each taxon into latitudinal bands with an edge of range code, including:

European Edge of Range Code	**Explanation of European Edge of Range Code**
N_1	absolute northern European limit between latitudinal band 45°N and 50°N
N_2	absolute northern European limit between latitudinal band 50°N and 55°N
N_3	absolute northern European limit between latitudinal band 55°N and 60°N
N_4	absolute northern European limit between latitudinal band 60°N and 65°N
S_1	absolute southern European limit between latitudinal band 45°N and 50°N
S_2	absolute southern European limit between latitudinal band 50°N and 55°N
S_3	absolute southern European limit between latitudinal band 55°N and 60°N

Species endemic to GB or confined in Europe to our area are excluded as they have no wider European distribution; infraspecific taxa are also excluded as they were not considered by Preston (2007). No taxa were categorised as being at the southern limits of their European range between latitudinal band 40°N and 45°N. New taxa that were not included in Preston (2007) due to their colonisation in GB in recent years and which are at the northern limits of their European distribution (*e.g. Serapias lingua* and *S. vomeracea*) are assigned to the appropriate range code. Taxa that were included in Preston (2007) that have since expanded their range to the extent that they now fall within a different latitudinal band *e.g*. *Mibora minima*, are assigned to the band that now applies.

7.1.11 *European/Global Red List assessments*
This column collates the most recent threat statuses published in European and Global Red Lists for native taxa in GB that are also present outside of our area and have been assessed. Publications used include, for Europe (E), the *European Red List of Vascular Plants* (Bilz *et al.,* 2011), *European Red List of Medicinal* Plants (Allen *et al*., 2014), *European Red List of Lycopods and Ferns* (García Criado *et al.* 2017), *European Red List of Trees* (Rivers *et al*., 2019), and globally (G), *The IUCN Red List of Threatened Species* (IUCN 2016).

7.1.12 *Change from 2005 assessment*
If a threat status in this Red List is different from the assessment published in Cheffings & Farrell (2005), then the change is highlighted as either an increased threat, or a reduced threat. For a few taxa, a reduction in threat status (from NT to LC) equated with differences between the two publications for the NT qualifying thresholds (see section 4.6) *e.g. Carex diandra, Cynoglossum officinale, Spiranthes spiralis, Wahlenbergia hederacea*. If the previous thresholds used for Cheffings & Farrell (2005) had been implemented for this Red List, then all of the example species above would have retained their NT status. This discrepancy is consistently highlighted in the accompanying notes.

7.1.13 *Notes*
When relevant, a brief explanation for the threat status assigned is given here.

8 A new vascular plant Red List for Great Britain

8.1 Appendix 1 Vascular plant Red List for Great Britain
See *Online Supplementary Information.*

8.2 Appendix 2 *Dryopteris affinis* aggregate
See *Online Supplementary Information.*

8.3 Appendix 3 *Hieracium*
See *Online Supplementary Information.*

8.4 Appendix 4 *Limonium binervosum* aggregate
See *Online Supplementary Information.*

8.5 Appendix 5 *Taraxacum*
See *Online Supplementary Information.*

9 Waiting and Parking Lists

9.1 Waiting List
The concept of Waiting and Parking Lists for taxa for which assessments could not be made was included in Cheffings & Farrell (2005). In effect, these lists comprise taxa which would be classified as 'Not Assessed' under IUCN Guidelines (2024).

Taxa are included in the Waiting List if there are currently insufficient distribution or population data upon which to base a threat assessment, and/or there are taxonomic uncertainties, or doubts or uncertainties regarding native, archaeophyte or neophyte status. It is not an exhaustive listing. Some taxa have been carried over from Cheffings & Farrell (2005) in instances where the uncertainties listed above have not been resolved to the extent that an assessment of threat can be undertaken. Many new taxa have been added since 2005, with the bulk of these comprising species or subspecies where taxonomic concepts either differ from Stace (2019), or have not been included in Stace (2019) but which nevertheless merit further attention. For example, pseudogamous apomicts within the *Ranunculus auricomus* complex are included here, as are numerous *Ulmus* taxa (both were treated in Sell & Murrell, 2018). For full Waiting List, see *Online Supplementary Information*.

9.2 *Parking List*
A taxon is included in the Parking List if there is now persuasive evidence that it is a neophyte rather than a native, native-or-alien or archaeophyte, or that it is not (or no longer) a valid taxon at subspecies or species level. As for taxa on the Waiting List, threat assessments for taxa on the Parking List have not been undertaken. The Parking List is not an exhaustive one that lists all neophytes, but rather one that focuses on taxa that have recently been classified as neophytes (*e.g. Fritillaria meleagris*), or where a better understanding of taxonomy has either resulted in their demotion below subspecies status, or as a synonym of a valid taxon (*e.g. Alchemilla minima*). Some taxa included in the Parking List in 2005 are also repeated here for clarity. In contrast to the Waiting List, further work on Parking List taxa is not considered to be a priority. For full Parking List, see *Online Supplementary Information*.

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